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Prevention of Malaria in Military and Naval Forces in the South Pacific

MALARIA TRAINING MANUAL NO. 1
NAVMED 141

(MEDICAL OFFICERS)

Prepared by Malaria and Epidemic Disease Control
South Pacific Area and South Pacific Force

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UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1943

PREVENTION OF MALARIA IN MILITARY AND NAVAL FORCES IN THE SOUTH PACIFIC

CONTENTS

THE PREVENTION OF MALARIA IN MILITARY FORCES IN THE SOUTH PACIFIC

I. Introduction.

Experience has shown that organized and properly directed preventive measures against malaria in military forces in the South Pacific Area, will check the disease to a degree which will permit the successful accomplishment of military operations. Failure to take steps, however, will result in an enormous degree of sickness and loss of man days, as might well be expected in the conduct of war on some of the most malarious islands in the world.

The control of malaria is a joint responsibility. It requires the cooperation of both line and medical officers, and of the men serving under them, and that their efforts be directed along productive channels by persons with special knowledge of the disease. The control of malaria further requires that all concerned have general knowledge of the manifestations of the disease, and particularly of the preventive measures which are applicable under special military conditions.

In the notes to follow, the general nature of the program being undertaken in the South Pacific Area is outlined; certain principles, which past experience indicates as best in the handling of specific problems are stated; and most important, various responsibilities are defined. In the actual application of measures enumerated herein, it is obvious that many modifications will be necessary and that considerable ingenuity will be required in order that the desired end result may be obtained.

II. GEOGRAPHICAL DISTRIBUTION OF MALARIA IN THE SOUTH PACIFIC AND CERTAIN ADJACENT AREAS.

A. Malarious Islands. Malaria is present in hyperendemic form on a large number of islands involved in the Pacific campaign. Certain other islands in near proximity, remarkably enough, are entirely free of malaria. From a practical standpoint, all islands of the New Hebrides and those North and West thereof may be considered malarious (North of 20 degrees S. latitude, to the equator, and west of 170 degrees E. longitude.)

B. Non-malarious Islands. New Zealand and New Caledonia are malaria-free, as are also islands of the Loyalities, Fiji, Samoa, Cook, Tonga, Society, Gilbert, Ellice, Hawaii, Tahiti, and Nauru and Ocean Islands. The absence of malaria in these islands is due essentially to the fact that no anopheline mos-

quitoes are present. Only mosquitoes of this genus are capable of transmitting the disease.

Although reports have indicated the presence of anophelines in New Caledonia as late as 1939, to date, no proven cases of locally acquired malaria have been encountered. Very recent surveys and those now in progress have not disclosed the presence of any anopheline species.

III. TOPOGRAPHICAL AND SEASONAL ASPECTS.

A. Topography. It is of highest importance in the selection of campsites on malarious islands that the remarkable difference in the malariousness of various parts of each island be recognized. Of two closely adjacent sites, equally satisfactory from a tactical standpoint, one may be highly dangerous and the other free of malaria. To prevent errors in selecting campsites, a directive has been issued, (Reference A, Par. 6), requiring that Malaria Control Units assigned to each base be consulted.

B. Season. In general, the prevalence of malaria in the South Pacific fluctuates markedly according to season. During the rainy season which usually extends from November to May, Mosquito densities are apt to become high, and during such periods the malaria incidence reaches its peak. One may expect a lag of one month following the onset of the rainy season before the incidence of malaria increases to any great extent. Similarly, a like period occurs after the end of the rainy season before the incidence declines appreciably.

During the dry season (approximately May to November) malaria rates may be expected to drop to relatively low levels.

IV. NATURE OF THE DISEASE IN THE SOUTH PACIFIC AND ITS TRANSMISSION.

A. The mosquito vector. Many species of mosquitoes have been identified in the islands of the South Pacific, but only one, **Anopheles punctulatus moluccensis,** Swell. and Swell., transmits malaria from man to man. All other mosquitoes are "pest" mosquitoes, and are harmless so far as their ability to transmit malaria is concerned. **A. punctulatus** breeding in the dry season is largely confined to quiet eddies along the grassy margins of streams. In the wet season it breeds additionally, in numerous newly formed collections of water over widespread areas. During the rainy season when breeding becomes intense, this species of mosquito becomes most indiscriminate in its choice of breeding places. Its larvae then may be found not only in clear pools of water, but in stagnant or muddy pools, occasionally in brackish water, and very rarely in small containers such as tin cans. A fortunate exception to this rule is that cocoanut half-shells, although a prolific source of pest mosquitoes, do not create an anopheline problem.

B. Reservoir of infection. Natives are the principal source from which the anophelines become infected and are able

to transmit the disease to troops. Studies on groups of apparently healthy natives have shown that as high as eighty per cent are carriers of the disease. Whenever natives have been imported for labor purposes and permitted to live near troops, or where camps have been established in near proximity to native villages, malaria has appeared, sometimes in epidemic proportions. After malaria has "seeded" troops, they in turn also become sources of infection.

C. Relative prevalence of the three species of malaria. Three of the known species of the malaria parasite have been found in the South Pacific: **Plasmodium vivax,** causing benign tertian malaria; **Plasmodium falciparum,** causing malignant malaria; and **Plasmodium malariae,** causing quartan malaria. The relative prevalence of the three types of malaria varies considerably. In very general terms it may be said that about one-half of the **primary** cases will be benign tertian, one-half malignant tertian, and one or two per cent will be of the quartan type. Although the strain of **P. falciparum** encountered in this part of the world has in the past been declared exceedingly virulent, in military forces it has caused but few deaths, and pernicious manifestations have been surprisingly infrequent. The strain causing benign tertian malaria, while rarely or ever exhibiting pernicious symptoms has created a serious problem because of its marked tendency to repeated relapse, despite adequate therapy. Malignant tertian malaria has not shown this tendency. The infrequent cases of quartan malaria have shown poor response to specific therapy and have recurred frequently.

V. TREATMENT OF MALARIA.

It is essential in the control of malaria that all cases be properly treated. The following outline gives principal points to be noted in the treatment of the disease based upon the experience gained from many thousands of cases in this area. Atabrine, the principal drug recommended, has been found to be eminently satisfactory in the treatment of malaria. This is fortunate in view of the potential shortage of quinine which demands its maximum conservation and the fact that the exclusive use of quinine in full therapeutic courses as a routine of treatment for all cases has been prohibited. (Reference B).

A. Specific Therapy.

1. Malaria-Uncomplicated (patient able to retain oral medication). **Combined quinine-atabrine-plasmochin treatment.** Quinine sulphate, 0.64 gram (10 grains) three times daily after meals for two or three days, until fever is controlled. **Concurrently** with the first administration of quinine give **atabrine,** 0.1 gram (1½ grains) three times daily, after meals, for seven days. (This overlapping of atabrine and quinine for the first two or three days permits a more rapid clinical response than occurs with atabrine alone.) After two days **without** antimalarial medication give **plasmochin,** 0.01 gram (3/20 grain) three times daily after meals for five days, except for the debilitated patient who should receive only two doses daily.

(**Caution:** plasmochin is issued both in 0.01 gram and 0.02 gram tablets. Discontinue or reduce dose if toxic symptoms occur. The most common are cyanosis without dyspnea and severe abdominal cramps). The addition of plasmochin to a course of therapy has been advocated by many authorities on the grounds that this drug will reduce relapse rates. In addition, plasmochin is stated to be able to destroy the crescents in falciparum infections, and therefore may be of some additional value in certain cases in preventing transmission. The administration of plasmochin requires careful medical supervision and should not be used by other than medical officers.

While the above treatment has been widely used in the past, more recent recommendations (August 1943) from both the War and Navy Departments suggest certain changes. The use of plasmochin no longer is recommendeud as a routine except for those cases of falciparum malaria which persistently show the presence of crescents. Another recommended change is the elimination of quinine from the quinine-atabrine combination as routine treatment. It has been proposed to give increased doses of atabrine initially, then to reduce this dosage to one tablet t. i. d. The use of larger initial doses of atabrine leads to a rapid clinical response such as that obtained by employing quinine in addition to atabrine. For the details of these changes direct reference should be made to the circulars which are to be issued shortly.

2. Malaria with coma. Quinine dihydrochloride, 0.64 gram (10 grains) in at least 200cc sterile normal saline, given intravenously **very slowly,** every eight hours until patient can retain oral medication; then treat as an uncomplicated case.

3. Malaria with vomiting. (Unable to retain oral medication).

(a) Atabrine dihydrochloride, ampoules, 0.2 gram (3 grains) in 7 cc. sterile normal saline, injected carefully into the gluteal muscles of one buttock; site of injection then is massaged thoroughly for two minutes. Care must be taken to avoid the sciatic nerve. Dose may be repeated if necessary in eight hours in other buttock. As soon as patient can retain oral medication, treat as an uncomplicated case.

(b) Quinine dihydrochloride, (To be substituted when atabrine is not available) 1.0 gram (15 grains) in 10cc. sterile normal saline injected intramuscularly as above. Dose may be repeated if necessary in eight hours in other buttock. As soon as patient can retain oral medication, treat as an uncomplicated case.

B. General principles in the treatment of malaria.

1. Prolonged courses of quinine or atabrine therapy, or combinations of the two and courses of therapy containing larger dosage than specified above have been tried many times in this area without apparent effect in reducing the relapse rate in the average case of malaria.

2. Period of hospitalization. Patients discharged to duty in less than ten days after the onset of symptoms will al-

most invariably suffer prompt relapse if sent to duty involving any considerable amount of fatigue or exhaustion.

3. Treatment of cases developing on suppressive therapy. Clinical cases which develop in spite of atabrine suppressive treatment (prophylaxis) may be treated with good results by the methods described above. The use of quinine alone to treat cases previously on atabrine suppressive therapy is not necessary. .

4. Continuance of atabrine during convalescence. There is no evidence that continuing atabrine in suppressive treatment dosage (0.05 gram per day), or in similar dosage, at the conclusion of a regular course of treatment is of benefit. However, post-treatment cases that are sent to duty with troops who are on suppressive treatment should follow the program of suppressive treatment if such is a routine in their own organization.

5. Use of intravenous drugs. The intravenous use of quinine should not be undertaken lightly; nor should it be withheld from patients who are critically ill as in such instances the danger of intravenous injection is far outweighed by that of permitting the disease to pursue its course uncontrolled.

6. Necessity of close observation in falciparum infections. Cases with malignant tertian malaria should be closely watched as at any time there is apt to be a sudden onset of serious symptoms. This is particularly true in patients whose thick films show enormous parasite densities of **P. falciparum.**

7. Blackwater fever. This disease of uncertain etiology, but probably a complication of malaria, is known to be present in endemic form on most of the malarious islands of the South Pacific. To date, few cases have appeared among troops. The disease is most apt to be seen in men who have been on malarious islands over six months, and in those who have had repeated attacks of malignant tertian infections of malaria.

8. Need of laboratory confirmation of diagnosis. Where competent thick film laboratory diagnosis is available, it is inexcusable to start treatment of the average case of suspected malaria without thick film verification of the diagnosis. Contrary to the opinion often stated, malaria cannot be accurately diagnosed early in individual cases on the basis of clinical symptoms alone. If the thick film is negative and the condition of the patient not urgent, repeated smears should be taken and the diagnosis of malaria and treatment withheld until a positive smear is obtained. Response to quinine does not prove that the patient had malaria; in fact, cases with repeatedly negative thick films are almost certainly not malaria. Obviously, in field and combatant conditions, cases should be most carefully observed in order that simulating disease does not lead to errors of serious consequence.

9. Routine thick films in all hospitalized cases. Early symptoms and signs in acute malaria occasionally mimic surgical and medical conditions. This is apt to cause occasional errors in diagnosis, which, however, may be prevented if routine thick films are required, irrespective of admission diagnoses, on all patients who have been exposed to malaria.

Another value of taking routine thick films is the detection of latent malaria which is common among patients who have been on suppressive treatment. When latency is present in patients who are suffering from trauma, shock, or are about to undergo operation, anti-malaria therapy should be undertaken promptly. If not done, latent malaria will almost surely become acute, and as a result may seriously jeopardize the patient's chance of recovery.

10. Treatment of latent malaria. When latency is detected by thick film examination, full courses of therapy should be instigated in the same manner as if the case were one of acute malaria. No modification in the treatment of such cases is necessary.

11. Disposition of malaria patients. The average case of malaria when adequately treated and allowed a proper period of convalescence is ready for duty. In certain cases, however, where malnutrition and physical exhaustion coexist, individuals who have had malaria will require prolonged periods of convalescence and should be evacuated to facilities which can best provide these. Another type of case requiring evacuation is the chronic relapser. Such individuals are those who for one reason or another respond poorly to treatment and spend so much time on the sick list that it is preferable that they be removed from malarious areas.

VI. SUPPRESSIVE TREATMENT. (Chemoprophylaxis.)

A. Indications for: Although there is no known drug which will prevent malaria infection, two drugs, atabrine and quinine, will under certain circumstances **delay the onset of symptoms of the disease.** These two drugs are therefore useful to keep men on their feet during urgent military operations where illness from any cause must be kept at an absolute minimum. Eventually, however, when the drugs are discontinued, those individuals who have become infected during periods of suppressive treatment, will become acutely ill with malaria.

B. Limitations. A very serious drawback to suppressive treatment is that it fails to hold acute symptoms of malaria in check when conditions of fatigue and exhaustion are experienced. Thus, in battle, its value decreases as these two factors increase, and large numbers of cases of malaria will appear at the very time suppression is most desired.

One of the most serious outbreaks of malaria occurred in an organization, which prior to entering combat, employed suppressive treatment for many months while under noncombatant conditions. Later, during the fatigue of battle, a large portion of previously accumulated latent cases became acutely ill, with the result that malaria appeared in epidemic proportions.

C. Drug of choice. Where suppressive treatment is essential, atabrine is the drug of choice. Not only is quinine prohibited for routine use (Reference B) but experience in this area has shown that atabrine is better tolerated and preferred by troops. In rare instances when individuals are unable to take atabrine, quinine may be employed in 10 grain daily doses as a substitute, provided that a medical officer has specified such to be necessary.

D. Atabrine intolerance. In the early phases of initiating a program of suppressive treatment, it is not uncommon for from five to ten per cent of individuals to show symptoms of intolerance. Under conditions of improper administration, a very much higher percentage of untoward reactions have been experienced in occasional groups. Usually in such instances it is found that the drug was administered on an empty stomach. Often the fairly large initial dose of two tablets (0.2 gram) will cause trouble in individuals; occasionally one tablet may do so. Reactions are unusual when one-half tablet (0.05 gram) is employed. Whenever diarrhea and enteritis have been prevalent in groups prior to the first administration of the drug, the amount of intolerance has been excessive.

The most common untoward symptoms experienced are nausea and vomiting, usually coming on several hours after taking the atabrine. Abdominal cramps and diarrhea are not unusual. Later on, during the continued administration of the drug, a yellowish discoloration of the skin may appear. This is not a sign of toxicity, but is due to the dye content of the drug, and will disappear after the drug is discontinued. The drug is a cumulative one and continues to be excreted for some time after its use is stopped.

After the phase of initial intolerance is over, it will be found that less than one per cent of any group will be unable to continue with the drug. Medical officers, by correcting the mistakes pointed out above, and by reducing the dose for temporary periods in individuals who experience difficulties will find but rare cases of persistent intolerance.

E. Dosage. Give one-half tablet (0.05 gram) daily after a meal with a full tablet (0.1 gram) on Sunday. This routine leads to relatively few cases of initial intolerance and virtually no cases of continued intolerance.

Under conditions of great military urgency, such as actual combat, the dose of atabrine should be increased to a full tablet (0.1 gram) daily and be continued for the duration of the emergency. It is preferable that this procedure be employed after troops have become adjusted on the smaller half tablet (0.05 gram) daily doses of atabrine.

F. Supervision. If conditions are urgent enough to necessitate atabrine suppressive treatment, it is equally urgent that a proper system of supervision of the taking of the drug be required as follows: that the drug be administered by roster to both officers and men; that a competent noncommissioned officer witness the actual swallowing of the drug by each individual; and, that by checking the roster regularly, all individuals who have not taken the drug be required to report and take sufficient dosage to equal that missed.

G. When to start suppressive treatment. Suppressive treatment should never be started before landing on a malarious base, except when the unit concerned anticipates active enemy engagement. Where this exception does not hold, medical offi-

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cers should advise their commanding officers to withhold atabrine until after arrival and until after consultation with the permanently based malaria control unit at the malarious island concerned. If atabrine is found to be indicated, it may be started without any fear of the malaria situation getting out of hand.

Active land combat, on the other hand, generally requires that the routine of administration be well established before landing. One or two weeks is sufficient.

H. Period of administration. Atabrine in a dosage of 0.4 gram weekly, has been administered continuously to troops for periods as long as ten months. Not a single case of serious effect has been observed following such administration. The drug appears to have a low degree of toxicity even when used for prolonged periods and in dosage greater than that previously considered as representing the limit of safety. Experimentation with larger than recommended doses, however, is, at present, unwarranted and dangerous.

I. When to discontinue suppressive treatment. On malarious bases, especially those in the more rear areas, the control of the disease may progress to the point where suppressive treatment is not warranted. In such cases, base malaria control units will recommend the discontinuance of the drug. This may be accomplished as follows: stop the drug in a representative sample of two or three hundred men, but continue it on all others. This will permit an estimate of the number of cases of malaria to be expected when all troops discontinue the drug. The problem then is the practical one of staggering groups off of suppressive treatment according to the availability of hospital beds.

Another indication for discontinuing suppressive therapy is the return of units to non-malarious bases. **In all cases the drug should be continued until arrival,** at which time the medical officer may investigate hospital facilities and stagger groups off suppression as outlined in the above paragraph.

VII. ORGANIZATION FOR THE DIRECTION OF THE CONTROL OF MALARIA.

Malaria Control Units have been established on all malarious bases. Their personnel, derived from the Army, Navy and Allied Forces, consists of malariologists, entomologists, engineers, trained technicians and other specialists in problems of malaria control. The direction of these units and all matters pertaining to malaria control in all forces is under the organizance of an Officer-in-charge, Malaria Control, South Pacific Area. This officer, in turn, is directly responsible to the Commander South Pacific area and South Pacific Force.

A. General duties. It is the duty of Malaria Control Units to formulate antimalaria programs applicable to all forces occupying each base. These units are responsible for the technical direction of such programs and are required to submit to Commanding Generals, or other senior authority of each base, reports and recommendations which will insure effective control of the disease. (See Reference A).

It is a further duty of these units to supervise and direct the efforts of control units required within each of the

various organizations serving at each base. In addition, they supervise and direct the efforts of mosquito control carried on by troop mosquito squads, by naval construction battalions, and by army sanitary companies.

B. Nature and scope of program. A peace-time program for control is neither possible nor applicable to the problem of fighting forces. Only rarely can the objective be the complete eradication of the disease. The contemplated measures must be such that the disease is suppressed to the point where it can constitute no real threat to the success of military operations. To attempt complete eradication would require diversion of man power and equipment vital to other phases of the war effort.

Although limited in the above respect, there still remains a very comprehensive undertaking, the scope of which is outlined in subsequent sections. (See section IX, seq.)

C. Malaria Control Units of non-malarious bases. Additional Malaria Control Units have been established on certain non-malarious islands. These units serve principally to contact organizations about to enter malarious regions and to assist them in formulating an effective program for the prevention of malaria. Their duties also concern measures for the proper handling of evacuees from malarious areas. They have the responsibility of seeing that all feasible measures are taken to prevent the introduction of anopheline mosquitoes into their islands.

VIII. COMMAND RESPONSIBILITIES IN THE CONTROL OF MALARIA.

A. The responsibility for the control of malaria within each organization. This rests with unit commanders. Directives (See Reference G) require that a special plan be placed in operation. Briefly, this plan (see appendices I and II of Training Manual No. 2) requires:

1. The appointment of a medical officer with specific duties and responsibilities in regard to malaria control.

2. The creation of "mosquito control squads" for mosquito elimination within and adjacent to the area occupied by the organization concerned.

3. The appointment of special malaria control inspectors to maintain a continuous check on the efficiency of measures within the organization.

4. A training program in malaria control so that all personnel may have an intelligent understanding of the disease and especially of preventive measures which may be employed by the individual.

5. The coordination of malaria control within the organization with the overall program of control which is under the direction of base malaria control units.

B. Special control units within organizations. Special units composed of personnel similar to those in base units are being assigned to Army and Marine Corps divisions. These units have the general duties and functions required by the organization described in paragraph A above. They remain with their own organizations at all times.

IX. PREVENTIVE MEASURES APPLICABLE TO MALARIOUS BASES UNDER NON-COMBATANT CONDITIONS.

In the following paragraphs the nature of preventive measures applicable to non-combatant bases will be outlined. These measures may be classified as follows:

A. Measures for the protection of individuals from mosquito bites.
B. Elimination of anopheline breeding places.
C. The control of carriers of malaria.
D. Reduction of clinical cases by chemotherapy.

A. Measures for the protection of individuals against mosquito bites.

1. Proper selection of camps. Reference has already been made to the importance of the selection of suitable camping sites, and to the requirement that malaria control units be consulted in each instance in which new sites are being considered.

From the malaria standpoint, the following general principles will govern: The terrain should be one that is unsuitable for the breeding of mosquitoes or one which can be easily rendered unsuitable. An entomologist is best suited to give an estimate of the malariousness of a given site. Besides actual breeding places, he takes into consideration the flight range of mosquitoes, the direction of prevailing winds, the proximity of natives, and breeding potentialities in both dry and wet seasons.

Because of the nature of the breeding habits of anophelines in this part of the world, it is frequently hazardous to locate camps on slow flowing rivers or streams. It is often preferable to pipe or otherwise transport water to more favorable areas away from rivers. This plan generally pays manyfold by preventing a large loss of man-hours from sickness due to malaria.

Steps should be taken to relocate camps in which the malaria rates are unduly high and where further control measures are difficult or impossible to accomplish.

Where the military situation permits, the consolidation of troops should be effected to lighten the burden of malaria control.

2. Screened protection. One of the most fundamental and effective measures for controlling malaria is the placing of individuals behind insectproof screens. As the project is one of considerable magnitude and will require time for general accomplishment, screening materials should be issued according to priorities. First priority should be given mess halls and recreation quarters, as such screened buildings will protect the largest number of men during the hours of dusk and night which are the important biting periods. Obviously the most exposed organizations should be afforded the protection first.

(a) Methods. While screened pre-fabricated housing is preferable, other more simple methods such as the screening of pyramidal tents with either cloth or wire netting, as carried on extensively and effectively in this area, should be tried. Mosquito-proofing should be supervised and should meet the specifications noted in the Technical Appendix.

Although **mosquito bars** are the most generally available and the most practicable means of screened protection, their usefulness has often been limited due to carelessness. Mistakes made in the past are that bars have been stowed aboard ships so as not to be immediately available upon landing. In certain instances the loss of such protection for even one or two nights has been followed by epidemics of malaria. Provisions should be made to secure not only sufficient mosquito nets so that each man may have one, but for an additional supply for replacement purposes. An inspection routine should be established which will insure that each man is sleeping under a net, and that the net is properly used. (See Technical Appendix).

3. Spray killing of mosquitoes. The killing of adult mosquitoes with pyrethrum sprays is a markedly effective measure of malaria prevention. The equipment and methods available for this purpose are described in the Technical Appendix. It will be noted that a new preparation, Freon-pyrethrum aerosol, in pressure cylinders is being made available. More recent experimental evidence indicates that insecticides are valuable not only in screened quarters, but are of potent effect in outdoor areas as well. A system of routine spraying should be required, and both indoor and circumscribed outdoor areas, wherever mosquitoes are prevalent, should be included. There is some evidence to indicate that sprays in addition to killing mosquitoes have a certain repellent effect which may persist for some time.

4. Repellents. Mosquito repellents are destined to play a far greater role in the prevention of mosquito bites and therefore in preventing malaria, than ever before. As will be seen by reference to "Use of Chemical Repellents" (Technical Appendix), new preparations are being made available which greatly exceed the effectiveness of those previously in use.

The prime importance of these preparations is that they may be used under military conditions in which no other protection from mosquito bites is feasible. Night sentries, jungle patrols, and other similarly exposed men should be required to use one of these repellents. Where malaria rates are high, their use in camps will often be indicated.

Despite the experimental indications of non-toxicity, individuals using repellent lotions should be alert to the possibility of skin irritation, particularly where usage is fairly constant.

5. Protective clothing. The use of headnets, gloves, and leggings should be required whenever feasible. It is of greater practical importance, however, that men should not be allowed to remain half-dressed during the twilight, night, and dawn hours, as negligence of this type has caused much malaria in the past. During the active biting hours shirts should be worn with sleeves rolled down, and wearing of trousers rather than

shorts required. A useful procedure is that of encasing the lower borders of trouser legs by drawing the socks up over the outside.

6. Outdoor exposures. It is important that men in attending motion pictures and other night outdoor gatherings are not unduly exposed. The screening of moving picture theaters may occasionally be feasible, but it is more practical to arrange that such gatherings be held only at well controlled locations found to be free of mosquitoes. Improperly dressed men should be excluded from outdoor gatherings.

Highly malarious areas should be out of bounds for troops, especially at night, except where military necessity requires their being there. Swimming should be prohibited after dusk and in the early morning; similarly, shower baths should be taken during day time and not during mosquito biting hours.

Often in non-combatant bases it is essential for troops to engage in practice maneuvers some of which are held at night. Authorities directing such maneuvers should make every effort to see that they are held in the least malarious parts of the island, and that a rigid enforcement of all applicable measures, such as have been described, be enforced to protect individuals against mosquito bites.

Night work in outdoor places should be reduced to an absolute minmum.

B. Elimination of anopheline breeding places. The elimination of mosquitoes is a joint responsibility of each individual bivouac group or camp and of the Malaria Control Unit. (See Reference C.) It is the duty of the latter to survey campsites, determine breeding areas, draw up programs of anopheline elimination, and to instruct and supervise men provided by the organizations concerned in the carrying out of these projects. Malaria Control Units are required to inspect routinely each area to check the effectiveness of anti-mosquito measures. Units will provide necessary material to all organizations.

The prime objective of this program is anopheline control which requires control measures of a specialized type. Pest mosquito control is not a responsibility of Malaria Control Units, nor should men assigned to anopheline control be diverted to the elimination of pest mosquitoes until the anopheline situation is well in hand.

In intermediate areas affecting various camps, but not the responsibility of any individual organization, control measures will be undertaken by personnel of Malaria Control Units. Under certain conditions, requests will be made of organizations most vitally concerned for their assistance in such areas.

1. Methods of mosquito control in camps. Much useful and practical information on the elimination of mosquito breeding will be found in the Technical Appendix. Emphasis in control measures should be placed upon development of permanent and semi-permanent projects to eradicate breeding places; otherwise a continuous oiling program is necessary.

2. Man-made malaria. A great number of man-created breeding places for mosquitoes have followed incidental

to engineering and construction projects. Much of this may be prevented. Considerable dependence will be upon engineering and construction organizations not only to prevent, but to aid in elimination of natural breeding places with the equipment already present in the area in which work is being carried on.

It is essential that prior to beginning engineering projects requiring impounding of water, or otherwise creating new malaria breeding hazards, the Malaria Control Units be consulted in order to effect a satisfactory solution of the problem.

C. The control of carriers of malaria. Two human carrier sources of malaria exist on malarious bases: that in natives and that in seeded troops.

1. Natives. The most important sources are the chronic carriers among the natives which have long been occupants of the various island bases. Natives imported from other malarious islands for labor purposes create an additional hazard.

Surveys conducted by Malaria Control Units throughout the area to evaluate the danger of natives from a malaria standpoint, have shown both resident and imported natives to be highly malarious. Single blood film examinations have often revealed as high as fifty percent of a group to be positive for malaria parasites. In addition, tuberculosis, bacillary and amoebic dysentery, filariasis, and other diseases of hazard to military forces are prevalent among such groups.

(a) Imported native labor. One of the most serious outbreaks of malaria in this area has been traced to the introduction of a native labor force in a troop area prior to the inauguration of an effective program of control to protect the troops. Until satisfactory control is established, native labor, either local or imported, cannot be employed except at the cost of losing many man-days of sickness in military forces.

(b) Specific measures to reduce the hazard of native carriers of malaria.

Mass therapy of highly malarious groups should be attempted by Malaria Control Units in order to reduce infectiousness of natives. It must be borne in mind, however, that there is considerable question as to the effectiveness of such measures. Programs for mass therapy on natives should be repeated at frequent intervals throughout the malarious season. The frequency with which these procedures should be carried out may best be determined by thick film blood surveys taken at various intervals.

Segregation of natives. No natives should be permitted to reside within one and one-half miles of bivouac areas. Occasionally it may be possible to move small groups of natives, with the permission of local authorities, to areas away from troops; usually it is more feasible to move the camps, or best to prohibit selection of campsites in areas adjacent to native settlements.

Restriction of movements of natives. Military settlements should be off limits to natives other than those whose employment in camps is essential. Native working parties

when engaged in labor in troop areas should carry on their activities during day-light hours, and be removed in time to avoid their being bitten by anophelines at work sites in the early morning and early evening hours.

Military personnel should not be permitted in native villages.

Antimalarial measures in native villages. Where troops must be in close proximity to native villages, not only should mass therapy of natives be contemplated, but Malaria Control Units and camps situated nearby, should by joint effort, carry on a careful anopheline elimination program centering around the villages. Spray killing of adult mosquitoes in native villages should routinely be carried out, preferably with freon-pyrethrum mixtures.

2. Control of carriers in troops. Actual experience, as indicated by surveys of military units who have suffered high malaria rates, does not indicate that even well seeded troops are important sources of milaria. Prompt diagnosis and thorough treatment is probably responsible. The early recognition of relapsing cases of malaria is important as during secondary attacks the patient is most apt to be infectious to mosquitoes. Routine follow-up of patients after treament will many times detect carriers who can then be promptly rendered non-infectious by proper treatment.

D. Reduction of clinical cases by suppressive treatment. Suppressive treatment should never be started prior to arrival at bases where combatant conditions do not exist. It is much more important that measures which actually prevent rather than those which suppress be attempted first. However, if malaria should appear in such numbers as to threaten seriously the efficiency of operations being undertaken, suppressive drugs may be started and continued until such times as the measures of protection may be afforded the troops.

In bases previously occupied, Malaria Control Units will already have been established and should be consulted upon arrival to determine the need for suppresive treatment at that base.

X. PREVENTIVE MEASURES IN TROOPS OCCUPYING MALARIOUS ISLANDS UNDER COMBAT CONDITIONS.

In no other organization is it more essential that a well formulated anti-malarial program be prepared and followed than in units about to enter malarious bases under active combat conditions. Contrary to what might be expected there are many important measures which may be taken.

A. Organization and plan for combating malaria. When information is first received of prospective operations on a malarious base, each major organization should appoint an officer to be known as "malaria control officer." His general duties should be to make an estimate of the malaria situation and to

formulate a program of antimalarial measures which will be applicable to the specific military operations contemplated.

(a) Season. The malaria rates to be expected will vary markedly according to the time of year in which operations are to be carried on, especially in the southern-most malarious islands, where the peak of the malaria season occurs during the period November to May. Operations carried on in other months will be much less effected by malaria.

In the Solomon group and northward, the malaria season begins a month or two earlier and lasts a month or two longer.

(b) Hazard due to prior occupation by natives and by enemy forces. If natives have been present on a base in any considerable numbers, the malariousness of the base to be occupied may be considered to be greatly enhanced. A further hazard may be that due to the presence of Japanese military forces. Malaria surveys have shown as high as 70 percent of Japanese prisoners to be positive for parasites, and over two-thirds of the positives to show gametocytes. Although it is doubtful that if any such high proportion of malariousness would be found in average groups, the findings suggest the real hazard to troops required to engage the enemy at close quarters.

2. Program for training. All officers and enlisted men should be made familiar with the general nature of malaria, its military importance, and with their respective duties and responsibilities in preventing the disease. The general scope of the training program should be as follows:

(a) Medical Officers. Where the medical officers have had little clinical experience with malaria, arrangements should be made to hold rounds in the wards of any hospital where malaria cases are being treated. Conferences should be held in order that there may be an agreement on the plan of treatment and disposition. A simple plan should be devised for the prompt reporting of malaria cases to the malaria control officer. He will require such information to detect unduly high malaria rates and institute proper corrective measures. If laboratory facilities are planned, enlisted technicians should be trained by Malaria Control Units for the laboratory diagnosis of malaria.

(b) Line Officers should be instructed in the mechanism of transmission of malaria, the nature of the disease, its treatment, and the effect upon troops. Malaria Training Manual No. 2, for all officers, may be obtained from Base Control Units and used as a guide for instruction.

The limitations of suppressive treatment should be explained to them as well as its value. Especially should the need of a rigid plan of individual supervision of suppressive treatment be emphasized, and a specific plan for such supervision be drawn up. The effect of fatigue and malnutrition as a factor which tends to largely nullify the value of suppressive treatment should be emphasized.

There should be a clear understanding of what is meant by malaria discipline, the function of which is almost

exclusively that of command. The value of contemplated preventive measures and the responsibility of officers to enforce such measures must be made clearly evident.

(c) **Enlisted men** should be given an intelligent concept of the nature of malaria, its transmission, and its importance both to themselves and to the success of the organization. Malaria Training Manual No. 3 may be used for this purpose. Most important, the men should be made thoroughly familiar with the measures which they as individuals must take for their own protection. It should be stressed that there will be full intent to see that all men fully comply with the measures of prevention. They should be specifically instructed in the importance of the proper use of a bed net, the value and limitations of suppressive treatment, and in the wearing of proper clothing.

3. Procurement of drugs and other malaria control supplies. Methods of obtaining, and estimates of quantities required for malaria control needs are outlined in appendices III and IV of Training Manual No. 2.

4. Bed nets. The malaria control officer should make plans to insure that every man will have the use of a bed net immediately upon landing, or at the earliest possible time that the military situation will permit their use. Replacements should be made available.

5. Repellents. He should procure insect repellents, instruct men as to their proper usage and arrange to make them available to all troops. Great emphasis should be placed on the value of such preparations and careful plans drawn up to insure their systematic usage. In this connection the feasibility of spraying with repellent both the skin surfaces and the clothes of men should be considered.

6. Insecticide. He should procure freon-pyrethrum cylinders and instruct the men in their use. It seems not unlikely that these cylinders will be of great value in spraying men sleeping in fox holes, and in spraying dugouts and other semi-open places on the front lines. (See Technical Appendix).

7. Anti-larval measures. He should organize his mosquito control squads so that the oiling of breeding places may begin functioning at the first opportunity permitted by the military situation. Chemical warfare decontamination hand sprayers are well suited for this purpose and if a gas attack impends, can be rapidly reconverted to their original use. Spare parts for these sprayers, especially rubber gaskets should be obtained. No. 2 navy diesel fuel oil is usually readily obtainable and arrangements for constant supply should be made. Oiling crews should be prepared to function behind front lines especially in rear echelons which are under less active combat conditions. The possibility of oiling operations in semi-permanent front line conditions and when enemy action is not great should be contemplated. Wherever oiling operations are found to be feasible they can be expected to reduce tremendously the malaria experience of the organization.

B. Malaria control program during phase of occupation.

1. The malaria control officer's duties during actual landing operations make him responsible that a rigid application of all possible measures is being undertaken. It is his duty to supervise oiling operations. He should be required to inspect troops in their separate locations, observe the malaria discipline, and make recommendations to proper authority when conditions are not satisfactory. In making his recommendations he should be particularly guided by the malaria rates reported by individual units.

2. Suppressive treatment. Paragraph E of section VI, discusses the dosage indicated under combat conditions. The malaria control officer should set up the most rigid system possible to see that each man actually gets and takes his drug. Roster lists, when possible, should be used, and it is highly important that a responsible officer or non-commissioned officer actually witness each individual swallow the drug. In small groups acting independently the senior non-commissioned officer should undertake this responsibility.

The first administration of suppressive treatment should be begun **prior** to the landing operations. This is done in order to overcome some practical difficulties. First, to start atabrine suppressive treatment during the heat of battle is doomed to failure, for unless a system of administration is already a matter of routine, it cannot be initiated under battle conditions. Secondly, many individuals show intolerance when atabrine is first administered and if the system is set up prior to landing such individuals may become adjusted to the drug and if not they can be placed on quinine 10 grains daily. Thirdly, experience in this area has repeatedly illustrated that the initial administration of atabrine to troops, concurrently with the prevalence of enteritis and diarrhea, which is so frequent in the early phases of landing operations, seems to greatly enhance atabrine intolerance.

3. Laboratory facilities for accurate thick film diagnosis for malaria should be established at the earliest possible date. The lack of such facilities has in the past led to confusion of malaria with such entities as respiratory infections, bacillary dysentery, infectious hepatitis, dengue, and other febrile diseases which may simulate malaria.

4. Establishment of Malaria Control Unit. The above plan places the responsibility for the control of malaria in the early phases of combatant operations upon the organizations taking part in such operations. As soon as combatant conditions subside to the point where entomologists, engineers, and other technical personnel can function effectively, one or more Malaria Control Units will be established. The scope of antimalarial measures will then gradually expand so as to include such a program as described in the section on Preventive Measures Applicable to Non-Combatant Bases.

XI. PREVENTIVE MEASURES APPLICABLE TO FORCES AFLOAT.

Relatively few cases of malaria have appeared among the crews of either naval or merchant ships operating in the South Pacific Area. The program for the prevention of the disease in such units is fairly simple.

A. General Measures. Using Training Manuals I, II and III as guides, lectures should be given aboard ship to familiarize all members of the crew regarding the nature of malaria, mechanism of its transmission, and the measures by which the disease may be prevented.

Medical Officers may extend their clinical knowledge of the disease by making rounds on the malaria wards of hospitals whenever ships make shore contact. At such times their laboratory technicians serving aboard ships should be trained by Malaria Control Unit laboratories in the thick film technique for diagnosing malaria.

B. Specific measures.

1. Anchorage. Where stops are made at malarious islands, ships should be anchored off shore as far as possible in order to minimize the danger of mosquitoes flying aboard. Usually one-half mile suffices, but the direction of the prevailing wind may reduce or increase the hazard.

2. Liberty. Although cases of malaria may result from sending working parties ashore, or by allowing liberty on malarious islands, the malaria hazard will be almost nil if contact ashore is restricted to daylight hours. Overnight liberty is apt to be exceedingly dangerous although this again depends upon the malariousness of the individual location and is a matter which may be determined by consultation with Malaria Control Units.

3. Suppressive treatment. Suppressive treatment should not be given to personnel remaining ashore for temporary periods.

4. Landing forces. Where landing force operations are contemplated, suppressive treatment may be required. In addition, other procedures, as outlined in the section Preventive Measures In Troops Occupying Malarious Islands Under Combatant Conditions, will be applicable and should be employed.

5. Survivors. It should be mentioned that in the past survivors of lost ships have been landed on malarious bases almost totally unprotected. In such cases serious epidemics of malaria, some of which may have been prevented, have followed brief periods of exposure. Where possible, ships with survivors should be diverted to non-malarious bases, or, at malarious bases, Malaria Control Units should be contacted immediately so that some sort of protection may be afforded.

6. Prevention of dissemination of anopheline mosquitoes to non-malarious islands and bases. Attention is called to a

directive (reference D), which specifies measures to prevent ships from conveying malaria mosquitoes from malarious to non-malarious bases. Freon-pyrethrum insecticide cylinders provide by far the most effective method of carrying out the killing of adult mosquitoes aboard ships, and should be used in preference to hand sprayers.

XII. PREVENTIVE MEASURES APPLICABLE TO INDIVIDUALS AND TROOPS PASSING THROUGH OR ON TRANSIENT DUTY AT MALARIOUS BASES.

A. Individuals. Not infrequently individuals must either pass through or perform duties for short periods on malarious islands. In the forward areas where malaria is apt to be most prevalent, the danger of contracting the disease may be considerable if no precautions are taken. The following rules can be laid down:

1. Take along a mosquito bed net if there is any question as to whether one can be obtained at destination.

2. After arrival. Avoid exposure to mosquito bites from dusk to dawn by getting under mosquito bed nets early in the evening and arising late in the morning. Before retiring search the inside of the net with a flashlight to kill any mosquitoes which may have obtained entrance. See that the net is arranged so that there is a minimum opportunity for arms and legs to come in contact with the net and allow mosquitoes to bite through. (Note: Persons sleeping in nets on arising usually note a large number of bites on the knees and elbows. An insect repellent should be taken along. Before retiring smear the solution on these particularly vulnerable parts.)

3. If it becomes necessary to be out at night, or dusk, or in the early morning, apply insect repellent to exposed surfaces at hourly intervals.

4. Try to sleep in screened quarters, if possible. If malaria is especially prevalent use a bed net as an additional precaution.

5. Suppressive treatment. The taking of quinine or atabrine to delay the onset of symptoms of malaria is not indicated during transient stays at malarious bases. Even on the more malarious bases, the individual's chance of getting malaria in such short periods as 10 days, if proper precautions are taken, are exceedingly small.

B. Troop movements. Occasionally, plans may call for troops to stop off for brief periods at malarious bases preparatory to further movements to other localities. In such instances, the following considerations are pertinent:

1. Stop-overs on the more malarious bases should be avoided if at all possible. Otherwise, in the confusion of landing and setting up temporary camps, the exposure to mosquitoes is apt to be great with the result that many cases of

malaria will follow. Where essential, it is preferable that brief stop-overs be made at bases where malaria is least prevalent. In such a case, it is advisable to send an officer to the stop-over base in time to make preparation for the reception of troops. This officer should contact the Malaria Control Unit at the base concerned in order to select a camp site least likely to result in malaria infections.

2. The movement should be so planned that the troops may land in the morning with sufficient time to set up camp and permit most of the men to be under their mosquito nets by nighttime. The men should have been previously instructed in the proper use of mosquito nets, insect repellents, wearing of mosquito proof clothing, and all other measures described in the section pertaining to preventive measures for forces occupying malarious bases.

3. The advice of the local Malaria Control Unit should be followed regarding the necessity of taking suppressive treatment.

XIII. PREVENTIVE MEASURES APPLICABLE TO AVIATION FORCES.

Although malaria in any member of a fighting force is a serious deterrent to fighting efficiency, its occurrence in flight personnel is apt to be particularly costly. In general, the principles and recommendations laid down in other sections apply even more importantly to aviators and ground crews, and these sections should be consulted by medical and line officers concerned with a view of inaugurating every feasible preventive measure. Certain problems, however, concerning the control of malaria in flight personnel require special consideration.

A. Screened housing. Aviators in their constant movement from base to base, frequently do not have the protection afforded in well established camps, and consequently, their exposure to malaria and other disease is increased. For this reason it is deemed highly important that insect proof housing should be provided for transient aviation crews. High priority should be given in the assignment of housing requested for such purpose.

B. Selection of airport sites. When the selection of airports on malarious bases is pending, the malaria hazards presented should be taken in account. By directive (Reference A, par. 6), it is required that Malaria Control Units be consulted in this regard and that their recommendations be given full consideration.

C. Individual measures. To a large degree the measures which will afford best protection to aviators depend upon the discipline of the individual. The use of mosquito bars when sleeping, and of mosquito repellent when exposed during biting hours, will alone greatly reduce malaria morbidity.

1. Mosquito bars. It should be required that bars be carried in planes in sufficient number to be available to each

member of the crew and responsibility assigned to insure that they are routinely and properly used.

2. Repellents. The systematic application of insect repellents during the mosquito biting hours should be prescribed and made a matter of routine. The distribution of repellents should be such that they will be available at all times.

3. Suppressive treatment. Drug suppression presents several problems peculiar to aviation forces.

(a) Drug tolerance in flight personnel. Quinine, even in small daily doses of 5 to 10 grains, appears to be contraindicated. The frequency of untoward symptoms, particularly ringing in the ears, deafness, and vertigo, render the drug potentially dangerous to pilots. Atabrine, on the other hand, after the phase of initial intolerance has been overcome appears to be safe. No noticeable ill effects have been reported by pilots even after prolonged use, and flight surgeons observing aviators flying under active conditions of combat and at altitudes of around 30,000 feet, have reported no noticeable ill effects from the drug.

It is important that pilots and members of their crews be grounded during the initial administration of atabrine in order that flight surgeons may observe for individual intolerance such as nausea, vomiting and diarrhea. These symptoms are apt to come on several hours after the first dose is administered, but will be rare if the drug is employed in the dosage recommended below.

(b) When indicated. When flight operations are largely confined to malarious bases and when crews remain only for short periods on non-malarious bases, suppressive treatment is indicated and should be continuously employed. Where flight personnel are stationed for more or less prolonged periods at airports where malaria is well under control, suppressive treatment should not be used.

(c) Dosage. One-half atabrine tablet (0.05 gm.) should be given daily after a meal, with a full tablet (0.1 gm.) on Sundays. The administration should be rigidly supervised and enforced by a plan which will give some promise of regularity in the taking of the drug. Where a single dose is missed, the next should be doubled.

Dosage during periods of fatigue and exhaustion. Flight surgeons may deem it advisable to increase the dose of atabrine to one full tablet daily (0.1 gm.) where crews are subjected to fatiguing and exhausting flight operations.

(d) When to discontinue suppressive therapy. Inasmuch as suppressive treatment does not prevent infection, and that malaria will remain latent only during the period in which fatigue or exhaustion do not precipitate symptoms, flight surgeons should discontinue the drug whenever operating schedules permit.

(e) Routine thick films. Flight personnel on suppressive treatment should, if feasible, be thick filmed every 10 days to detect latent cases. Malaria Control Units at all bases

will render this service upon request if other laboratory facilities are not available.

(f) Post treatment observation of malaria cases. The high relapse rate of the malaria strains found in this area require that flight personnel who have been ill be kept under most careful supervision after treatment. Routine thick films should be periodically taken as a post-treatment measure (if possible at weekly intervals for three or four months). Inasmuch as a potent factor in precipitating relapses is early return of men to fatiguing duties, pilots should be grounded at least 10 days and preferably more, following the cessation of treatment. Aviation personnel who have had attacks of cerebral malaria should be carefully observed during convalescence to detect minor neurological disturbances which might easily be missed.

4. Prevention of dissemination of mosquitoes by aircraft. Freon-pyrethrum insecticide pressure cylinders are available for the spraying of airplanes. This preparation is superior to hand sprays and has the advantage of being non-inflammable. These cylinders should be made a part of the equipment of all planes which are apt to fly between the various bases.

Pilots are responsible for the spraying of their own planes (Reference E & F), and strict enforcement of the procedure will be required.

XIV. PREVENTIVE MEASURES APPLICABLE TO NON-MALARIOUS BASES.

It is essential that island surgeons, or other senior medical authority at non-malarious bases, institute all possible measures to prevent the introduction of malaria:

A. Check upon the proper spraying of ships and planes. Routine inspection should be established to insure that directives requiring the spraying of ships and aircraft (Reference D, E, & F) are properly carried out.

B. Mosquito control at airports. The elimination of mosquito breeding places at airports is a measure which will help prevent anopheline mosquitoes from becoming established on non-malarious bases. Programs of draining, ditching, filling, and oiling should be very thorough in areas adjacent to landing strips. Continuous surveys for mosquito larvae and adults, either by entomologists, or individuals trained by them, should be carried on at each airport. Malaria Control Units may be called upon to assist in outlining the program of control.

C. Reports on cases of malaria presumed contracted on non-malarious bases. All medical organizations should be instructed by island surgeons to report immediately if a case of malaria is encountered which appears to have been contracted on a non-malarious base. The serious implications of reports of this nature are obvious, and thorough, responsible investigation should follow. Blood films confirming the diagnosis of malaria should be obtained and kept for future reference.

D. Reports on finding anophelines on non-malarious bases. Similar instructions should be issued to require that

when suspected anophelines are found, either larvae or adults, that a report be rendered immediately, and specimens in question be preserved to permit a verification of the species diagnosis.

It is requested that Malaria Control Units be notified of reports of the nature referred to in paragraphs **C.** and **D.** above.

XV. TECHNICAL NOTES ON CERTAIN CONTROL MEASURES APPLICABLE UNDER MILITARY CONDITIONS.

(Extracted in part from War Department Circular letter No. 22, 16 January 1943).

A. Protection by screening.

1. Screening. The following general principles should be observed if screening is to give its full value as an antimalarial measure.

(a) The screening must be so applied that breakage will be minimal, and that the doors and windows will not facilitate mosquito passage. For instance, screen doors should open outwards, and should be on the windward side of a building, if possible. They should be strongly constructed so they will not sag or warp. They require springs so that they will close automatically. The places where a foot or hand would naturally be applied to open a screen door should be protected with a cross strip of wood or metal. Screen doors should shut against battens, which are strips of wood or metal, to block entry of mosquitoes through the space between door frame and door.

In highly malarious areas it is desirable to have double screen door barriers with a vestibule between.

(b) Careful attention must be paid to the closing of all possible apertures not screened, such as cracks and knot holes, spaces where floor or wallboards have separated, openings between flooring and walls, corner openings where joists come together, holes where window shutter propsticks extend into a room for easy handling, ventilating pipes and shafts, etc. Holes may be covered with tin shingles or pieces cut from ordinary tin cans. A filler for holes and cracks may be made by boiling shredded paper and flour into a fairly homogenous mass and then adding sand and cement to form a plastic which may be moulded into the holes. This filler is somewhat pliable and will retain its place fairly well. Toilet paper is a suitable tissue for use in making this filler.

(c) Proper routine maintenance of screening is essential, with prompt and effective repair of rents and tears, and discovery and blocking of new cracks and knot holes. In malarious areas, the great importance of these apertures for mosquitoes is out of proportion to their seeming insignificance. The soldiers who occupy hutments and barracks should be

taught to make all minor repairs. Strict supervision of screening is essential. Under some conditions it may be desirable to assign an enlisted man as mosquito-proofing maintenance orderly whose duties it would be to inspect all screening at regular intervals, making such repairs as are within his capabilities and reporting others to proper authorities.

(d) Types of screening material. Steel wire screen cloth which has been galvanized is suitable and the most economical for semi-permanent buildings. Standard 18 mesh-wire should be specified.

For less permanent dwellings fine cloth netting is very valuable. The material should be a 20 mesh, stiff bobbinet, preferably dyed khaki.

2. Use of sleeping nets. Nets to protect sleeping individuals are useful in preventing malaria but they must be properly employed and properly maintained. They must be so adjusted and used that mosquitoes cannot feed through the mesh because the net touches the individual. The lower edge must be so tucked in that no opening is available for mosquitoes to enter. Overhead frames should be provided for bed and cot nets. These should not have sharp points which will catch and tear the netting. Nets used in small tents should be suspended from and conform to the shape of the interior of the tent. Shelter tents nets should not be used over the outside of the tents but hung inside. The nets should be folded up by day. When the net is entered at night the interior should be inspected for stray mosquitoes. Rents in nets may be repaired with adhesive tape, sewing or patching.

B. Protection by spray-killing adult mosquitoes.

1. Pyrethrum insecticides. Pyrethrum flowers contain active principles which are grouped under the term pyrethrins and kill all species of mosquitoes and certain other insects by destructive action on the central nervous system. The sprays are non-toxic to man and animals (although liberal application of a kerosene-pyrethrum spray to the skin may cause local irritational inflammation). Pyrethrins rapidly disintegrate by a photochemical catalytic reaction when exposed to sunlight and oxygen. Pyrethrum concentrate and sprays should be kept in tightly stoppered, light-proof containers. Containers should never be left open in the sun. In sealed containers pyrethrum extracts will maintain their potency for a year or more, even in the tropics. If a pyrethrum spray fails within three minutes to kill all the adult mosquitoes with which it comes into contact, it no longer contains the standard amount of pyrethrins and is not suitable for use.

Three types of pyrethrum products are supplied. There is first a 20-1 concentrate, each gallon containing the oleoresins of approximately 20 pounds of flowers, with not less than 75 to 100 grams of total pyrethrins per gallon, or 2 to 2½ grams per 100 cc. This 20-1 concentrate is diluted with 14 parts of a good quality of water-white, preferably odorless, kerosene and

may be sprayed from various types of mechanical sprayers, such as are described below.

Secondly, in areas where there may be difficulty in obtaining kerosene for diluting the concentrate, a prepared ready-to-use pyrethrum spray is supplied. This conforms to Class AA rating, as defined in the Department of Commerce Standard Specifications. This rating is based on actual performance killing tests and these AA sprays will contain 150 to 180 mg. of pyrethrins or their equivalent per 100 cc. With either of the above two sprays, about one-half ounce is required to spray effectively 1,000 cubic feet.

Finally, pyrethrum is supplied in containers holding a mixture of 20-1 concentrate, oil of sesame, and liquid freon, as described below.

(a) Freon-pyrethrum aerosal. Pyrethrum may be dispersed from pressure cans or cylinders containing a maximum of 1 percent pyrethrins, 2 percent oil of sesame, and 97 percent freon. (Freon 12 is dichloro-difluromethane.) The oil of sesame is a synergist or activator, and enhances the killing power of the pyrethrins. The vapor pressure of the freon produces the necessary spraying pressure, which does not decrease as long as a drop of liquid is present in the closed container. As the freon containing the insecticide is sprayed it forms a fine mist from which the solvent evaporates almost immediately, leaving the pyrethrum and sesame suspended in the air as a cloud of fine droplets called an aerosol. The freon is non-toxic to man and mosquito and it is non-inflammable. It is used simply as an expellent to disperse the pyrethrum and oil of sesame.

The pressure in freon cylinders varies with temperature. For example, it is 37 lbs. per sq. in. at 40 degrees F., 84 lbs. at 80 degrees F., 116 lbs. at 100 degrees F., and 205 lbs. and 140 degrees F. Various types of freon-pyrethrum pressure cans and cylinders are available. One pound of freon-pyrethrum mixture is sufficient to spray about 150,000 cubic feet of space when properly used. It is liberated in 12 to 14 minutes of continuous use. To spray a room, hutment, or native dwelling, the can is carried rapidly toward all corners of roof, ceiling, or floor while the spray is allowed to escape. No direct hits on mosquitoes should be attempted, as this wastes spray. About 4 seconds of spraying per 1,000 cubic feet is usually sufficient in military huts. Somewhat longer spraying for the same cubage is generally required for native huts. It is best to spray under the eaves of a hut before going inside. The freon-pyrethrum spray is so effective that it can be used sparingly and without waste.

(b) Hand atomizers or spray guns. Small household-type guns are useful for casual spraying of quarters. They consume relatively greater amounts of insecticide than other types of sprayers, but may be used to advantage by the troops themselves for occasional spraying.

Paint gun sprayer assemblies. Pyrethrum insecticides can be effectively sprayed through an ordinary paint gun

if a source of air pressure of 15 pounds or more is supplied. The source of the pressure may be in tanks pumped by hand or by gasoline or electric motor-driven compressors. Solidified carbon dioxide (dry ice) when available, in suitably constructed pressure tanks, is a good expedient.

C. Protection by the use of chemical repellents. Various essential oils and synthetic products have been used, as creams or lotions applied to the skin, to repel mosquitoes. Most mosquito repellents have had one or both of two major defects: (1) very transitory or weak effect, and (2) risk of toxic poisoning by absorption through the skin, especially when the repellent must be used liberally during extended periods of time. For example, diethylene-glycol is a mosquito repellent but is reported to be toxic when absorbed through the skin and apt to damage kidney and liver tissue if used freely for considerable time.

Three good repellents, 612, indalone, and dimethylphthalate are being made available to military forces. Of these, 612, will give protection against mosquitoes for about four hours after liberal application even under sweating conditions. Indalone will do about as well, except under sweating conditions when it should be renewed half-hourly. Dimethylphthalate is slightly less effective than 612, but more effective than indalone. All are better than any repellent available heretofore.

D. Anti-larval measures within and adjacent to camps.

1. Semi-permanent measures.

(a) Clearing. The cutting of grass and clearing of brush within and near camps apparently is of value by decreasing available daytime hiding places for adult mosquitoes.

(b) Draining and filling. Puddles and small pools constitute the chief breeding areas of **A. punctulatus** during the wet season. A good system of drainage will reduce the number of such places which otherwise would require continuous oiling. A few shovelfuls of dirt will eradicate many prolific breeding pools.

2. Larvicidal oiling.

(a) Discussion. Suitable oils, properly applied, will kill the aquatic stages of all species of mosquitoes and will also destroy sheltering vegetation at the edges of breeding places. The chief killing factor is a toxic action following contact with the tracheal cells of larvae and pupae. Consequently, the best larvicidal oils are those which penetrate most quickly, and with the greatest toxic effect, into the spiracles and thence into the trachea of larvae and pupae. What is required is a cheap, toxic oil or mixture of oil of suitable toxicity and viscosity which, when sprayed on the surface of the water, will spread well and form a uniform, persistent and stable film. The best larvicidal oils will kill in less than 30 minutes under these conditions. Number 2 diesel fuel oil, a more or less standard item on the supply lists of troop units, adequately meets all these requirments.

The ideal specifications for a larvicidal oil are the following:

Specific gravity 20/4—0.83–0.86.

Viscosity (Saybolt Universal at 100 degrees F.)—31–43.

Initial boiling point—297 degrees—414 degrees F. (165 degrees–230 degrees C.).

Final boiling point—Maximum—800 degrees F. (426.7 degrees C.).

Spreading coefficient—Minimum—17.0.

Kerosene or gasoline may be used as larvicides and will give a good kill, but they form transitory films, are expensive, and may constitute a fire hazard. Occasionally it may be desired to kill all larvae in a well by a film of gasoline, which soon evaporates, leaving no taste in the water. Lead gasoline should not be used in wells from which the water is used for drinking.

Because of their relative nonvolatility, waste motor oils and crude oils are not highly toxic to larvae. However, heavy applications of these oils will so contaminate small collections of water (this method can be safely used only on pools that are not subject to excessive movements or overflow) that breeding is prevented for extended periods of time. In the absence of proper larvicidal oils for routine spraying operations, these oils may be also utilized by mixing them with kerosene, generally in the proportion of 1 to 3, respectively, adding if possible about 2 percent of castor oil. However, the amount of kerosene to be added will have to be determined by experiment.

(b) Application of oil. General. Oil may be effectively applied to small collections of water by means of an oil-soaked broom, an oil mop, or oil-soaked waste tied to a stick. An ordinary waterpot may be used to pour oil on small collections of water.

(c) Sprayers. The knapsack sprayer consists of oil container, hand pump, and spray nozzle, and is carried and operated by one man. The ordinary sprayer has a capacity of 4 to 5 gallons and a spraying range of about 25 feet. The knapsack sprayer is a practical and economical apparatus for applying oil to ditches, small ponds, or other collections of water which can be reached by the spray.

(d) Continuous oilers. Where long stretches of small streams or ditches are breeding mosquito larvae, it may be feasible to use some method of continuous application of oil.

Drip oilers have proved very efficacious in this area. A tin or drum of about 5 gallons capacity is placed on supports over a stream or ditch so that oil will drip on the water surface. The size of the hole will govern the amount of oil dropping from the container. In homemade containers a nail hole may be used, with a nail left loosely in the hole. It

may be necessary to use some string to form a washer around the nail head. The can should be several feet higher than the stream surface so that oil will spread quickly when drops strike the water. The rate of flow required to furnish a satisfactory film depends on circumstances. Generally, an average flow of from 10 to 20 drops per minute will suffice for each foot of width of water in the stream.

Submerged oilers are containers having two small openings. The are designed so that when sunk to the bottom of a stream or pond, their oil will escape through one opening and be replaced by water which enters through the other. These cans have the disadvantage that they are difficult to adjust so that oil will flow properly, as the openings are easily clogged.

Oil may be applied continuously by means of a weighted **submerged bag of oil-soaked sawdust.** Or **oil-soaked sawdust** may be scattered over the surface of a breeding place.

(e) Amounts of oil required. Using diesel oil No. 2, about 9 gallons are required per acre of water surface for complete coverage with a uniform, stable oil film. With any ordinary knapsack sprayer of the Panama type, one laborer can oil about five acres of breeding area per day, if the terrain is not difficult. In usual practice the amount of oil necessary to produce a uniform film may vary from 10 to 20 gallons per acre. The amount of floatage and vegetation will make a considerable difference. It is usually necessary to spread oil once a week.

(f) Care of equipment. Equipment for spreading oil larvicides requires careful maintenance. It should be overhauled and thoroughly cleaned at reasonable intervals. Full sets of replacement parts should be stocked.

XVI. REFERENCE LIST OF DIRECTIVES PERTAINING TO MALARIA CONTROL IN SOUTH PACIFIC AREA.

(A) All Forces, COMSOPAC, Ser. No. 0094b. Subject: Malaria Control Units, South Pacific Area, dated 13 November 1942.

(A) Army, Headquarters USAFISPA, Subject: Malaria Control South Pacific Area, dated 29 November 1942. Modification; 24 May 1943.

(B) All Forces, COMSOPAC, Air-Mailgram, dated 10 February 1942. Conservation of Quinine.

(B) Army, Headquarters, USAFISPA, Memorandum, dated 14 February 1943.

(C) All Forces, COMSOPAC, Ser. No. 00169E, Subject: Mosquito Control Measures in the Prevention of Malaria in the South Pacific Area, dated 29 December 1942.

(D) All Forces, COMSOPAC, Ser. No. 0176, Subject: Prevention of Dissemination of Anopheline Mosquitoes to Non-Malarious Islands and Bases, dated 17 January 1943.

(E) All Forces, COMSOPAC, Ser. No. 0178, Subject: Prevention of dissemination of malarial mosquitoes by aircraft, dated 2 September 1942.

(F) All Forces, COMSOPAC, Ser. No. 0174, Subject: Prevention of dissemination of malarial mosquitoes by aircraft—responsibility for, dated 7 February 1943.

(G) All Forces, COMSOPAC Ser. No. 01619, Subject: Antimalarial organization and training program within military units, dated 13 September 1943.

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